# Numerical modelling of three-dimensional fracture propagation in layered materials using parallel computing

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Detection and tracking of cracks are of significant importance in engineering analysis and design. This is due to the high maintenance and repair cost of the damaged structures. Cracks initiating from the surface of the material may penetrate into the interior when subjected to loads. Furthermore, the spatial pattern of these cracks could be very complicated and may not be easily predicted using traditional theoretical and experimental methods. As such, there is a need to develop robust numerical models that help in the analysis of crack growth so as to develop efficient strategies to combat the issues arising from the growth of inherent defects and cracks [1].

Recently, phase-field method has gained in popularity for modelling crack propagation [2]. In the phase-field method, fracture is treated as a smeared zone in the continuum that has completely lost its mechanical strength. These models offer several advantages. Firstly, they offer a means to model arbitrary crack paths independently of the underlying finite element mesh. Secondly, they adopt an energetic approach to dictate both the initiation and propagation of damage. Coalescence and branching are naturally treated within the framework as damage is obtained as an additional nodal field on a given background mesh [3].

However, a major weakness of the phase-field method is its high computational cost. This method achieves mesh objectivity by regularizing the crack over a band of finite elements with some minimum bandwidth. As such, a two-dimensional domain requires meshes in the order of $10^6$ elements and a three-dimensional domain requires meshes in the order of $10^9$ elements. This colossal computational cost prevents the method from being utilized in realistic engineering applications at present.

In this study, we develop a robust three-dimensional phase-field model to simulate crack propagation in layered subsurface systems, by leveraging parallel computing. We implement the hybrid phase-field model of Ambati et al. [3] in deal.II–an open source finite element library [4]. This model will then be utilized to perform several numerical experiments and examine the effects of contrast in parameters such as elastic stiffness, fracture toughness and interface inclination on fracture propagation in layered subsurface formations with perfectly bonded interfaces. Conclusions will be drawn on the conditions that result in fracture arrest, deflection and penetration at layer interfaces in layered formations.

## References

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